<u>REMARKS</u>

Claims 1-16, 21-23, 26-28, 30, 32, 34, and 38-49 are pending in this application, with claims 1 and 21 being independent. Claims 32, 45, and 46 have been amended to correct the informalities noted at paragraph 3 of the Office Action.

Claims 1-7, 10-15, 21-23, 26, 27, 39-43, and 47-49 were rejected under 35 U.S.C. § 103(a) as being obvious from U.S. Patent Application Publication No. US 2004/0001661 A1 to Iwaki in view of the publication by Cumpston et al. entitled "Two-photon polymerization initiators for three-dimensional optical data storage and microfabrication", Nature, vol. 398, March 1999, pp. 51-54 (hereinafter Cumpston); claims 8, 9, 28, 30, 32, 38, and 44-46, as being obvious from Iwaki in view of Cumpston and further in view of U.S. Patent No. 6,684,007 to Yoshimura; and claims 16 and 34, as being obvious from Iwaki in view of Cumpston and further in view of U.S. Patent No. 5,255,070 to Pollak.

Applicants submit that independent claims 1 and 21, together with the claims dependent therefrom, are patentably distinct from the cited references for at least the following reasons.

As an initial matter, for the Examiner's convenience Applicants are enclosing herewith a (colored) document with additional information as to the present invention, to support the below arguments and aid in the Examiner's understanding. Pages 2 and 3 of the enclosed document cover the principles of Two Photon Absorption (TPA). Page 4 shows prior art TPA structures which are obtained from wet chemical techniques, as opposed to the present 3D structuring. Page 5 lists the most notable steps of the present TPA structuring technique. Pages 6 and 7 show waveguides realized with this 3D TPA structuring. Pages 8 and 9 show the refractive index distribution of the present waveguides which have a gradient index profile, in contrast to step index profiles obtained with conventional techniques.

Finally, pages 10 and 11 show how the components of the printed circuit board are mounted.

Claim 1 is directed to a printed circuit board element including at least one optical waveguide provided in an optical layer and at least one optoelectronic component in optical connection with the optical waveguide. The optical layer is a single layer of a photoreactive material capable of Two Photon Absorption (TPA) processing. The optoelectronic component is embedded in the optical layer, and the optical waveguide, which is structured by irradiation and a Two Photon Absorption (TPA) process (see, e.g., the paragraph bridging pages 4 and 5 of the present specification), and which adjoins the optoelectronic component, is present within the optical layer.

Therefore, the present printed circuit board element, as claimed in independent claim 1, relies on a single optical layer (designated by reference numeral 3 in the drawings of the present application, for example) consisting of a single material, within which the optical waveguide (designated by reference numeral 6, for example) is structured by a two photon absorption process. Accordingly, there is a unitary, single-layer structure which is subjected to laser radiation freely focusable in all three dimensions in this single optical material, so that the optical waveguide can be formed without restrictions as to its 3D shape.

In contrast to this, the prior art optical elements provide for a multi-layer structure with at least a lower and an upper cladding layer enclosing an independently formed waveguide core layer which has a higher refractive index than the surrounding cladding layers. From Iwaki it is further known to apply UV radiation to a previously formed waveguide core layer for increasing the refractive index of this - already independently formed - core layer. This is, however, merely an alternative to having a waveguide core layer made of a material which has high refractivity already without this treatment.

On the other hand, it is a novel feature of the present invention to actually and directly

form a waveguide in a single optical layer by focusing an intense laser radiation within this single optical layer, thereby inducing two-photon absorption processes which locally change (increase) the refractive index of the exposed portions.

In contrast, the optical element according to Fig. 1 of Iwaki is obtained from a fundamentally different process, and the resulting optical element shows a merely visual resemblance with the circuit board element as of Fig. 1 of the present application. Indeed, a visual comparison might lead to the assumption that both figures illustrate equivalent structures, as is submitted in the present Office Action. However, in contrast to the invention, layers 104, 105, and 106 of Iwaki are distinct, independently formed layers, where subjection to UV radiation is merely one option for increasing the refractive index of the previously formed core layer 105.

As can be inferred from paragraph [0069] in connection with Fig. 7A of Iwaki, the optical element is prepared by press molding, where a concave portion for forming the optical waveguide core layer 105 is provided in a film of a material with a relatively low refractive index serving as the lower cladding layer 106. Subsequently, a second polymer with a higher refractive index is filled into the concave portion to form the core layer 105. These distinct layers are pressed together using a mold. As an alternative way to provide for a core layer 105 with a high refractive index, it is also shown to subject the core layer 105 to UV radiation, thereby increasing the refractive index of the - already formed - core layer (see the last sentence of paragraph [0069], and paragraph [0054]).

However, in both cases, Iwaki relies on a multi-layer structure consisting of distinct layers attached to each other by press molding, wherein the optical waveguide cladding layer 106, formed in an optical waveguide layer 104, is pressed together with the core layer 105 which is formed by a polymer filled into a concave recess of the cladding layer 106. The

previously formed core layer 105 can - optionally - be subjected to UV radiation for increasing its refractive index instead of choosing a polymer with a higher refractive index in the first place. Therefore, according to this prior art technique, it is necessary to apply at least two optical layers onto a substrate, whereas the present invention requires only one single optical layer, within which the waveguide originates from subjection to focused laser radiation inducing local changes in the refractivity.

Thus, in contrast to Iwaki, the present circuit board element is formed from a homogenous, single optical layer, where an optical waveguide structure is obtained by three-dimensional positioning and focusing of a laser beam within this single layer, so that the resulting optical waveguide structure is surrounded by the remaining optical layer.

A fundamental difference in the technique of the present circuit board element, as compared to Iwaki, is accompanied by clearly distinguishable features of the resulting elements which are, however, not evident from a simple visual comparison of the resulting structures. The present TPA structuring results in a waveguide with a gradient refractive index which stems from the intensity distribution of the laser beam. In contrast to this, optical elements obtained from conventional methods as disclosed in Iwaki have a stepindex distribution owing to the use of two different materials (see paragraph [0054] of Iwaki).

Furthermore, the waveguides obtained with conventional techniques are essentially restricted to rectangular cross shapes (see paragraph [0048] of Iwaki), whereas the cross-section of the present waveguides is generally oval or circular and can be designed to change in propagation direction which is hardly feasible with known techniques. Also, the waveguides in the state of the art have to be positioned directly onto the cladding layer. In contrast to this, the present waveguide can be freely formed in all three dimensions within the single optical layer.

Cumpston et al., on the other hand, discusses a variety of techniques associated with Two-photon excitation processes, which are known *per se*, as has already been acknowledged in the present specification (see the explanations in connection with WO 01/96915 A2 and WO 01/96917 A2, which specifically refer to this article of Cumpston, cf. p. 2 of the present description, English text).

The inventive concept of the present subject-matter lies in structuring a waveguide core layer within a single optical layer by TPA induced processes. Cumpston, on the other hand, refers to 3D lithographic microfabrication (3DLM, cf. second para., left column on page 53 of Cumpston), where an intense laser beam is focused within a photopolymer. Through this localized photoexcitation, the solubility of the exposed material is reduced, and a desired 3D structure is obtained by dissolving away the unexposed material.

This is clearly different from the present invention, where a 3D waveguide is directly formed within a single optical layer, so that the resulting element comprises a core layer surrounded by the remaining optical layer which has not been illuminated. Contrary to this, according to Cumpston, the remaining unexposed portions of the material are washed away so that a 3D structure without coating or cladding is obtained (cf. the uncoated waveguide according to Fig. 3c of Cumpston).

In order to obtain a full circuit board element with a coating and a core having a higher refractive index than the coating, as results from the present technique, at the technique of Cumpston it would be required to coat these lithographically microfabricated 3D structures shown in Cumpston with distinct cladding layers. Thus, Cumpston does not go beyond Iwaki in that a plurality of distinct layers need to be combined to obtain one circuit board element.

Furthermore, the tapered waveguide according to Fig. 3c of Cumpston is a 3D object;

however, no 3D TPA structuring is disclosed, as each polymerized layer is attached to the neighboring layers giving rise to a "stack of logs"-structure (cf. p. 53, right col., l. 2,3 of Cumpston). With this technique, only a small number of "pseudo"-3D objects can be realized, contrary to the present invention, where real 3D objects, without restrictions as to their shape, can be formed.

Hence, even a combination of Iwaki with Cumpston (assuming such a combination would be permissible) cannot lead to the claimed subject matter. Accordingly, independent claims 1 and 21 are seen to define a novel and non-obvious, and therefore patentable, invention.

The other claims in this application are each dependent from one or the other of the independent claims discussed above and are therefore believed patentable for the same reasons. Since each dependent claim is also deemed to define an additional aspect of the invention, however, the individual reconsideration of the patentability of each on its own merits is respectfully requested.

This Amendment After Final Rejection is believed clearly to place this application in condition for allowance and its entry is therefore believed proper under 37 C.F.R. § 1.116. At the very least, however, it is believed that the formal objections have been overcome. Accordingly, entry of this Amendment After Final Rejection, as an earnest effort to advance prosecution and reduce the number of issues, is respectfully requested. Should the Examiner believe that issues remain outstanding, the Examiner is respectfully requested to contact Applicants' undersigned attorney in an effort to resolve such issues and advance the case to issue.

In view of the foregoing amendments and remarks, Applicants respectfully request favorable reconsideration and early passage to issue of the present application.

Respectfully Submitted

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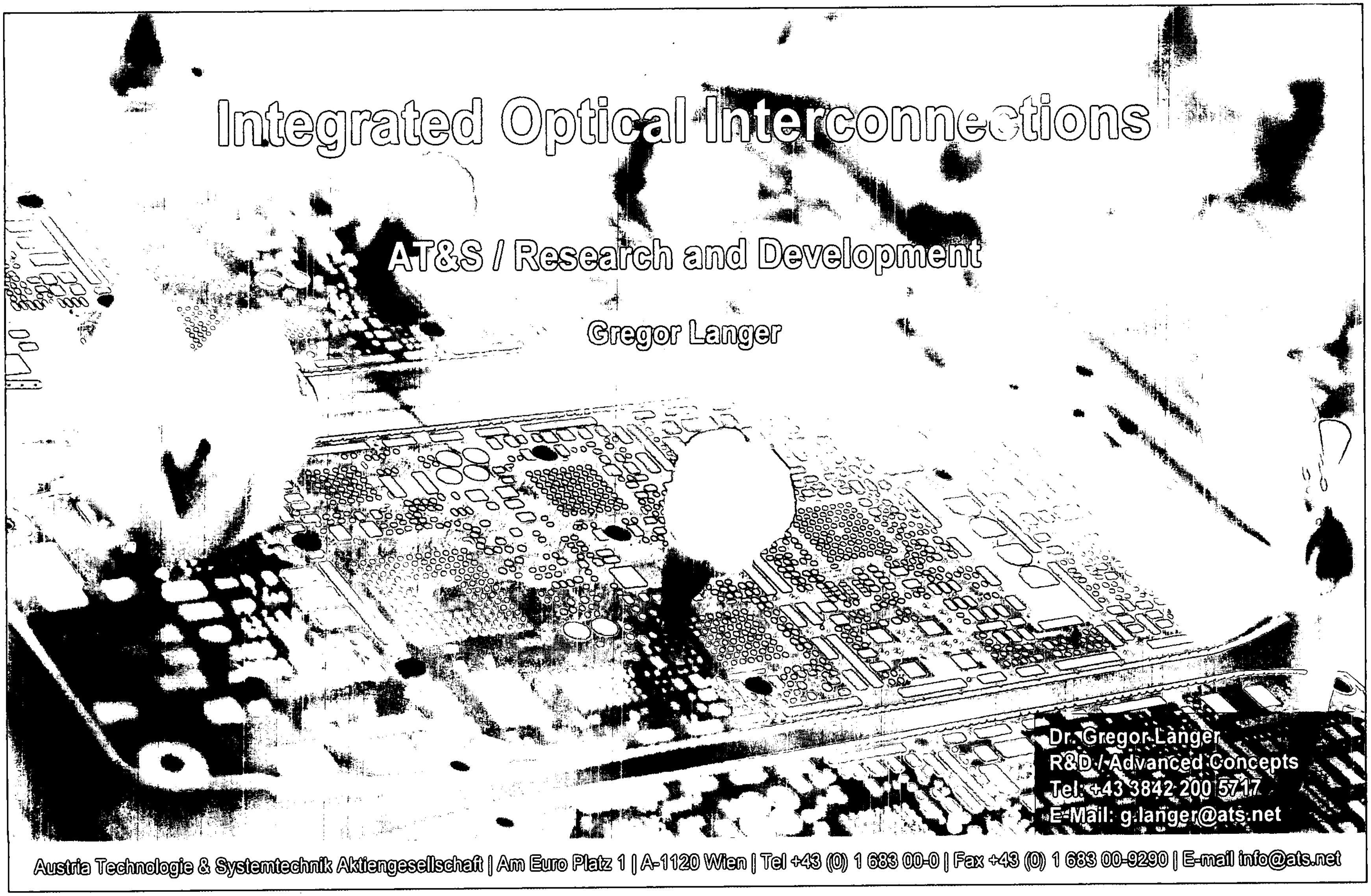

Mechanism of Two Photon Absorption (TPA)

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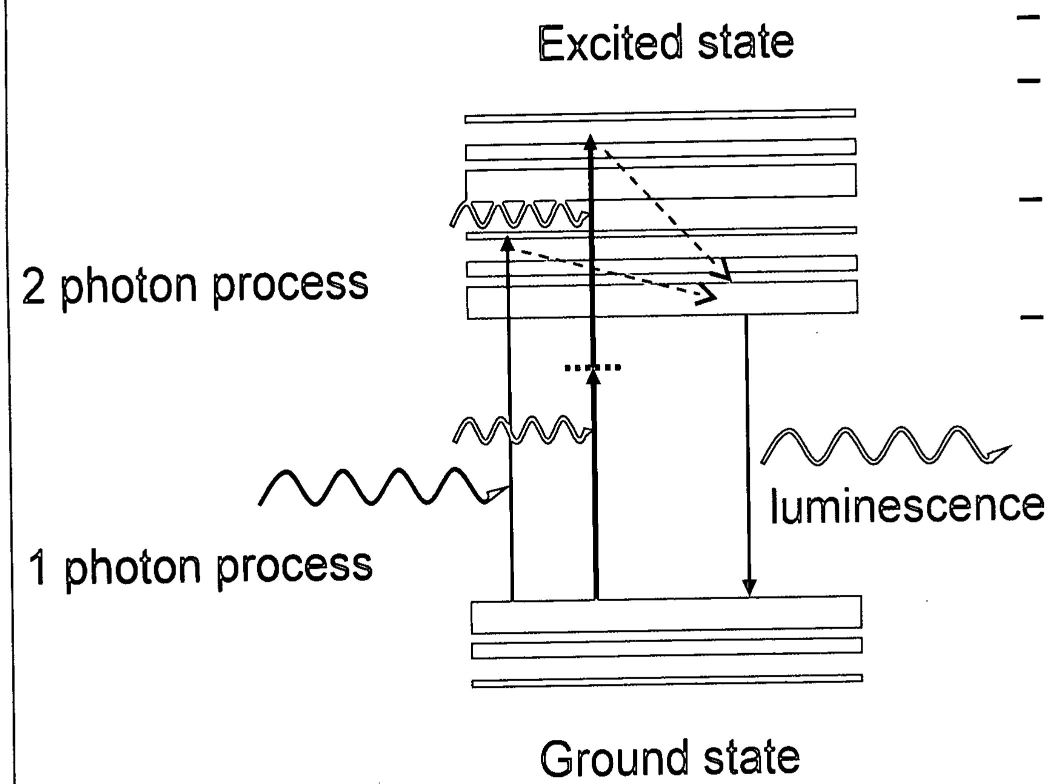

Two-Photon-Absorption (TPA)

- Non linear process (prop. I^2)
- Absorption via virtual intermediate state
- High laser intensity required due to short life time of intermediate level
- Luminescence: Photonenergy of emitted light is higher than incident light

TPA fundamentals

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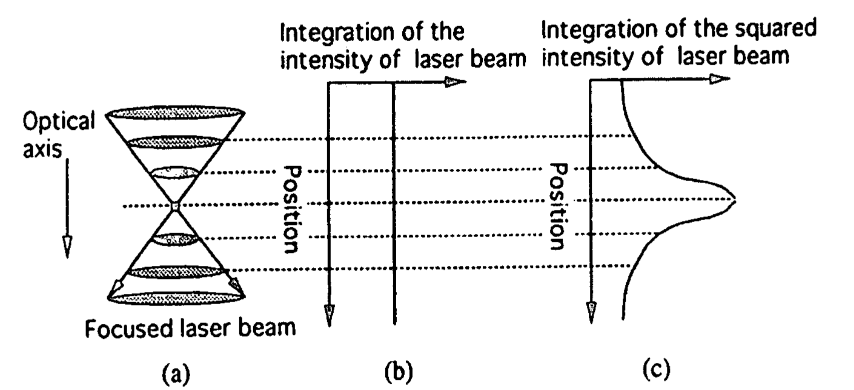
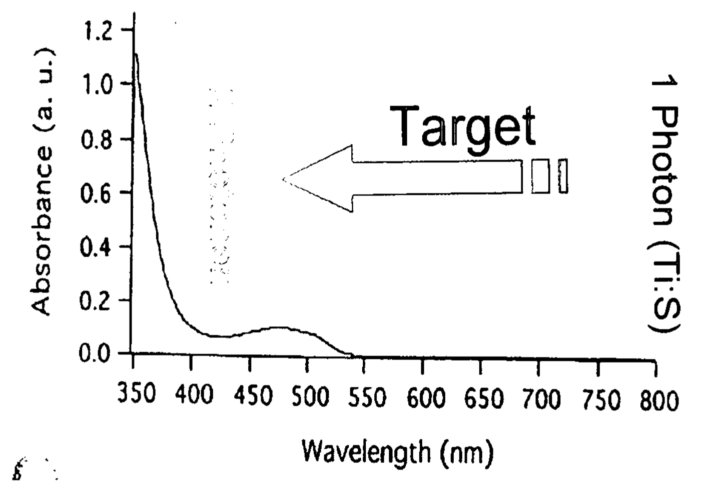
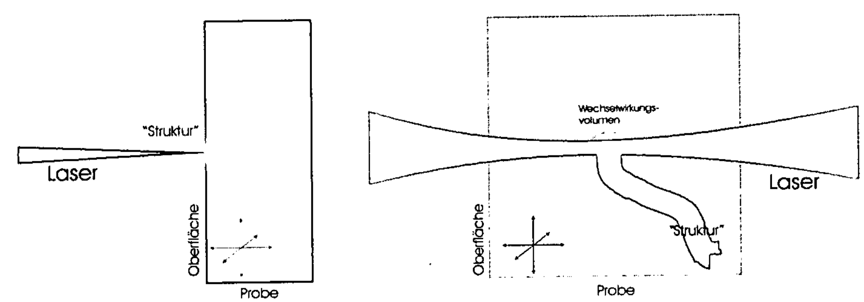


Dependency of I^2 along laser beam axis



Resist Absorption



One Photon Absorption (only 2D structuring) vs. Two Photon Absorption (3D structuring)

Examples of TPA-structures

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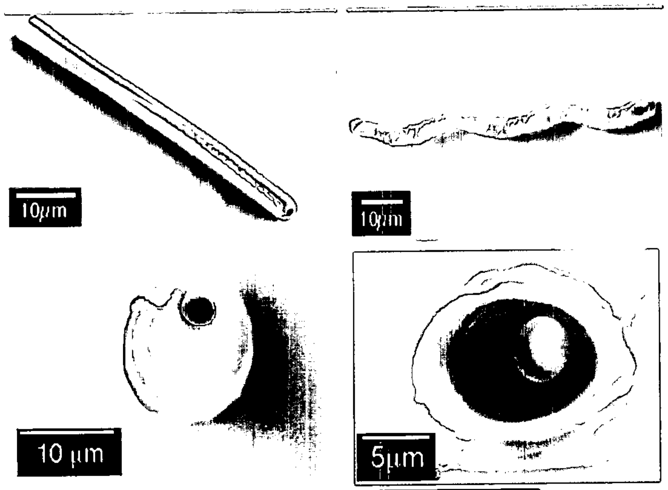
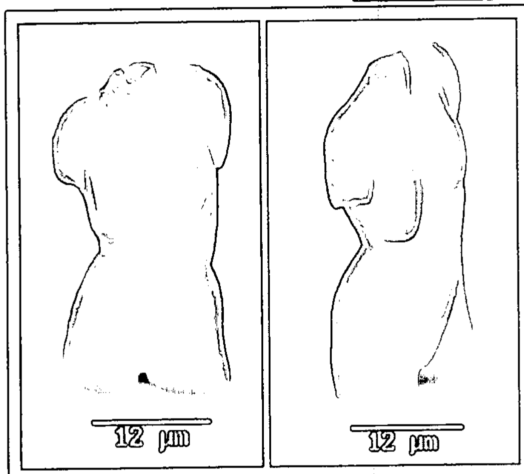
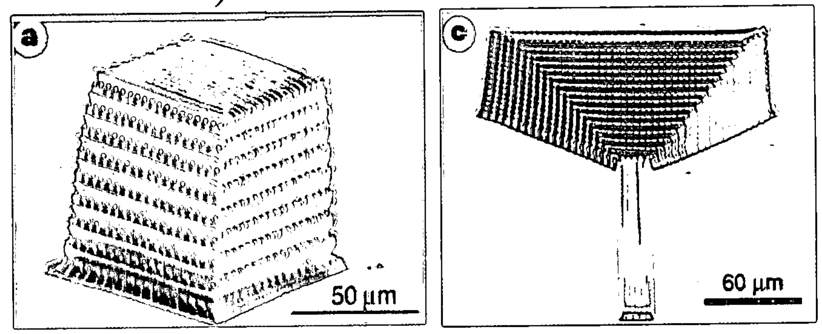
State of the art (development of TPA structures)



H.-B. Sun

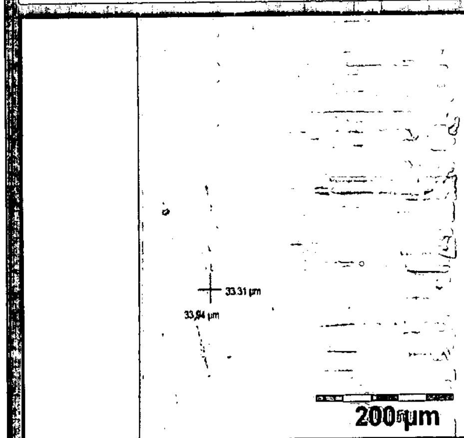


J. Serbin



B. H. Cumpston

New TPA approach



Cross section of TPA-written waveguide arrays: Due to the TPA irradiation there is an increase of the refractive index of the core structures, which are not developed.

New TPA Approach: Board Assembly

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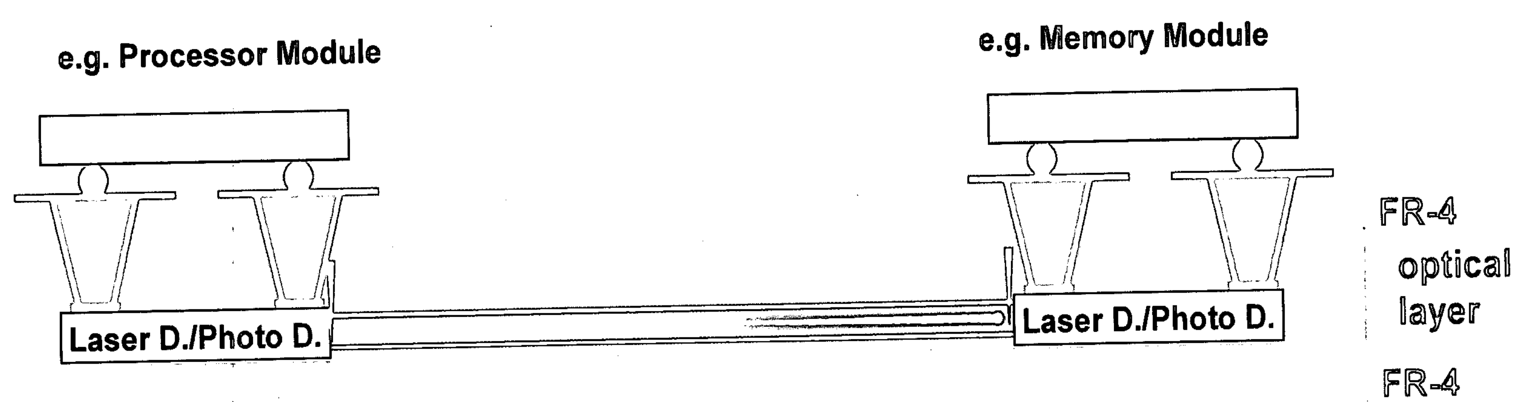
- Placement of o/e components onto PCB inner layer (standard precision)
- Application of optical layer
- Waveguide structuring between the o/e components using TPA (Two Photon Absorption)
- Thermal fixing step
- Lamination of surface plane
- Connection of the embedded o/e components using µ-Vias
- Surface mount assembly of components



New TPA Approach: Waveguides

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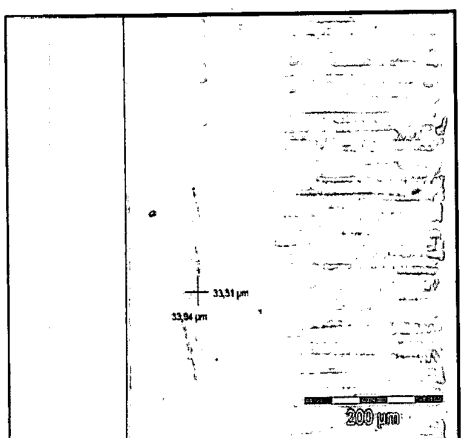
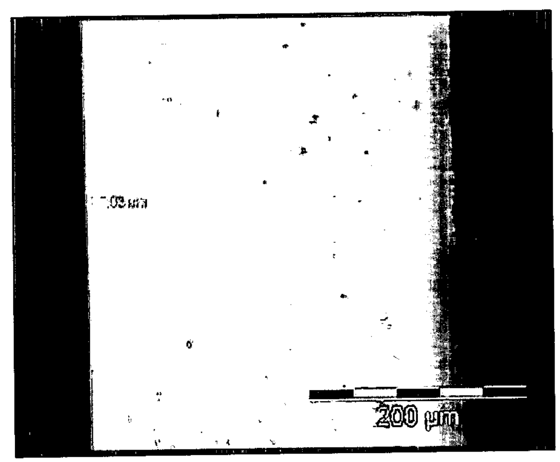
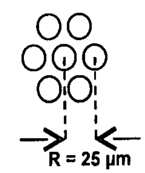
Cross section of TPA structured single waveguides and waveguide bundles

With this approach it is not only possible to realise single waveguides with different cross section diameters and forms (left), but also to realise multi waveguide structures like e.g. waveguide bundles (right).



Array of single waveguides (d = 20 – 35 µm)





Waveguide bundle (1:6) (d ~ 70 µm)

New TPA Approach: Waveguides

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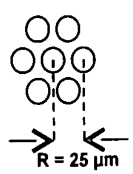
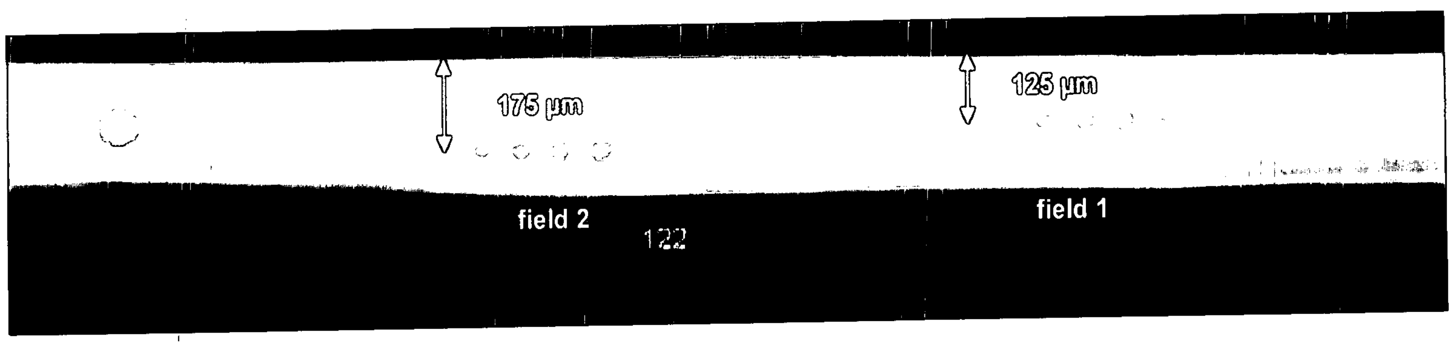
Cross section of TPA structured single waveguides and waveguide bundles

Due to the 3-dimensionality of the TPA structuring method, it is possible to realise the different waveguide structures in different depths of the optical material





New TPA Approach: Waveguides

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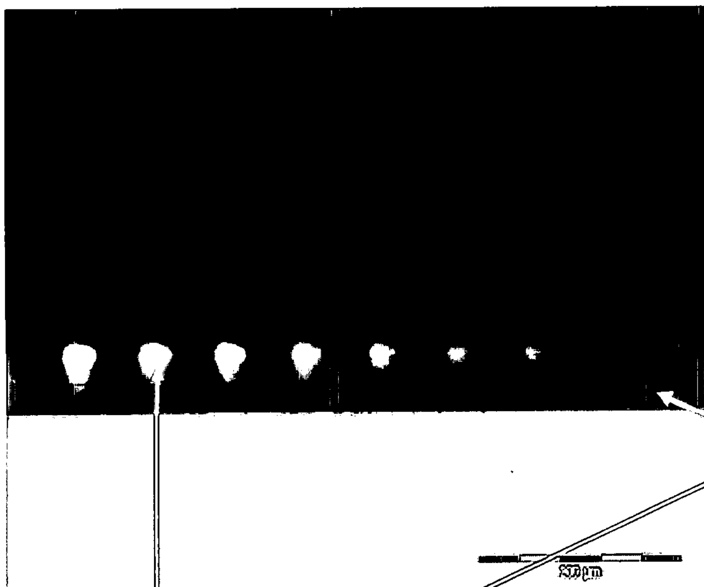
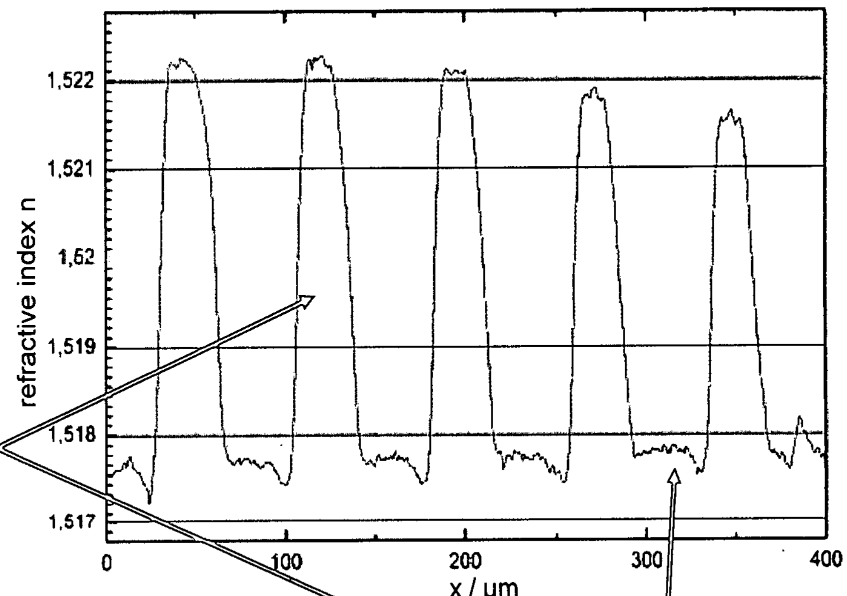
Index profile of TPA structured waveguides



Cross section of optical layer and waveguide array



Refractive index line scan of waveguide array

The core area shows an higher refractive index (gradient index profile) than the cladding area (core and cladding are resulting from the same optical material)

New TPA Approach: Waveguides

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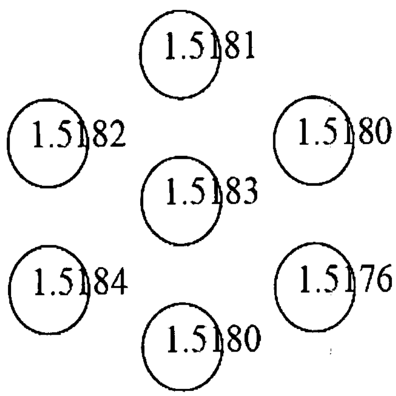
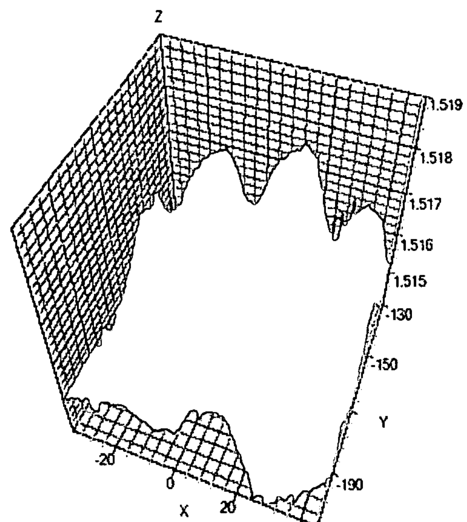
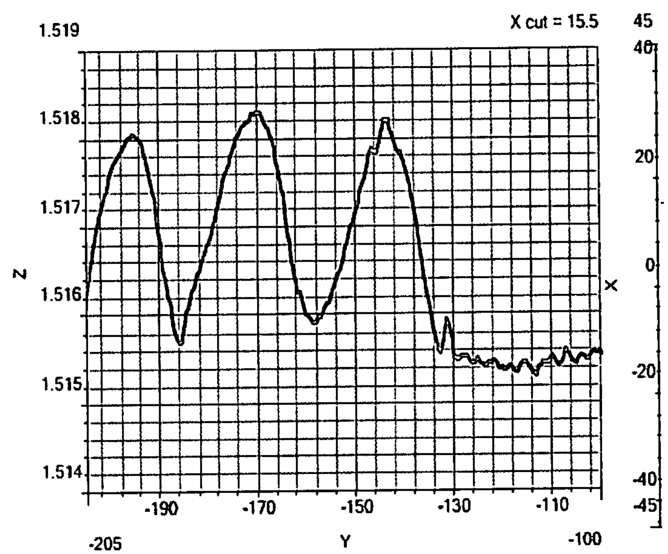
Index profile of TPA structured waveguide bundle







Refractive index measurement of a waveguide bundle:

left: refractive indices of single waveguides (n of cladding material = 1,5150)
middle: 3D refractive index profile
right: 2D refractive index scan

Such waveguide structrures are not realisable with state of the art structuring methods

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New TPA Approach:
Waveguide – component coupling

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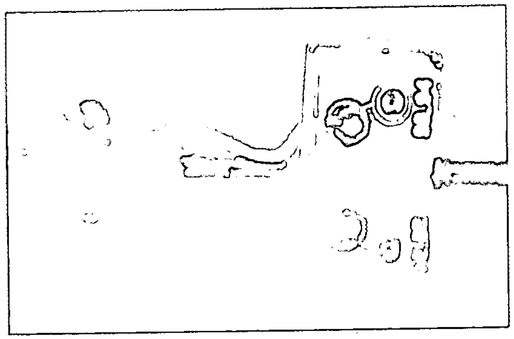
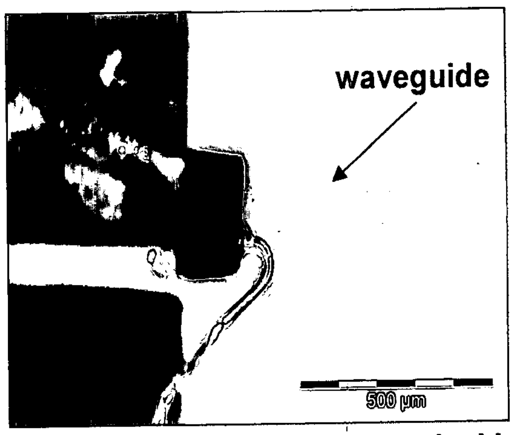
Coupling: Laser diode - waveguide bundle

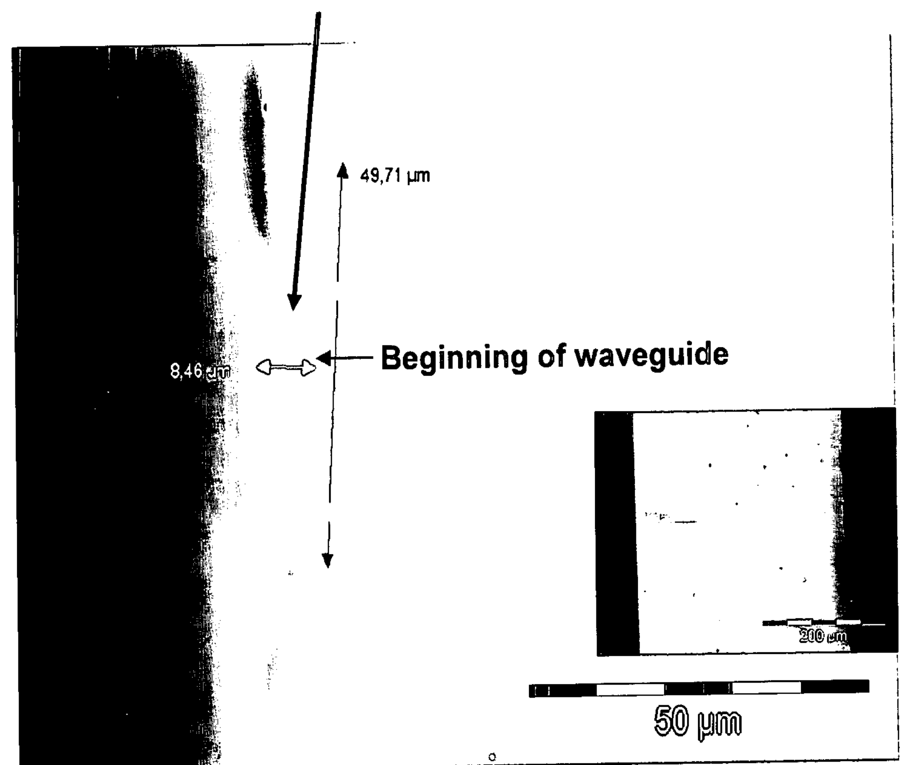


Attached laser diode (front side)



Laser diode embedded in optical layer with waveguide bundle (top view)

Exact positioning of waveguide possible



Laser diode light emission field and structured waveguide bundle

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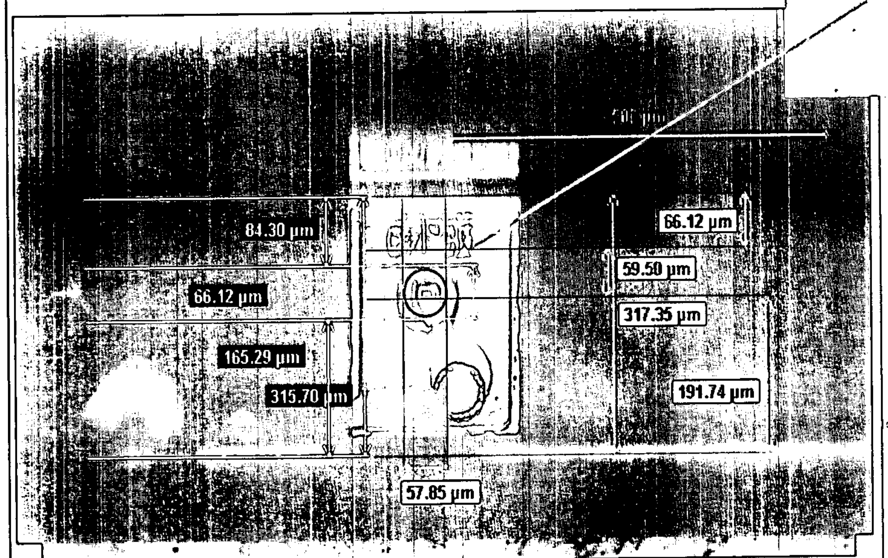
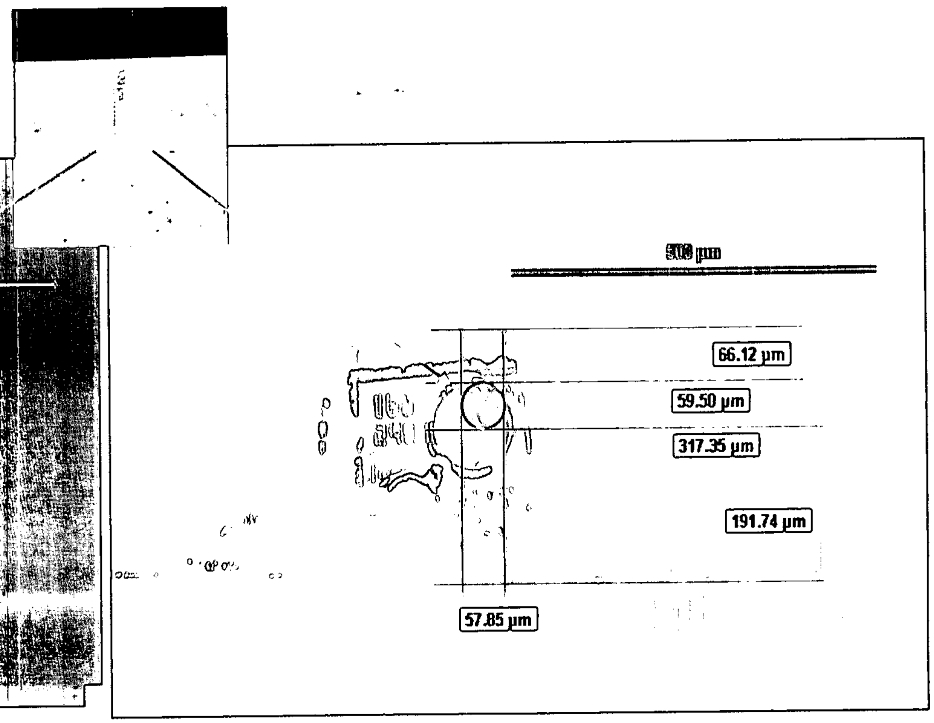
New TPA Approach: Waveguide – component coupling

Cross section



Waveguide bundle in front of active area of the laser diode



Waveguide bundle in front of active area of the photo diode

Due to the 3-dimensionality of the TPA structuring method, it is possible to couple the waveguide exactly to the required position in front of the component (first the component is attached to the board and embedded in the material, then the waveguides ist structured)